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Bulletin No. 10

ENGINEERING EXPERIMENT STATION
IOWA STATE COLLEGE
AMES, IOWA

DREDGING BY THE HYDRAULIC METHOD

BY

G. W. CATT, C. E.

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BULLETIN No. 10

DREDGING BY THE HYDRAULIC METHOD

BY

G. W. CATT, C. E.

We desire to call attention to the accompanying paper on "The Hydraulic Method of Dredging" by Mr. George W. Catt. At first thought this subject might seem not to be one of immediate interest in Iowa, but with the great increase in the use of cement the methods of securing sand at low expense and in large quantities, especially in the case of our larger cities, have become of great importance. It has already been proposed in some cases to establish hydraulic dredging plants for this purpose and hence we have considered that it would be of interest to print Mr. Catt's paper in full.

Mr. Catt is president of the largest dredging company in the United States, a company which constantly has under contract millions of dollars worth of work in localities scattered from the Atlantic coast to the Philippine Islands, hence he is able to speak on this subject with authority.

DREDGING BY HYDRAULIC METHOD

By G. W. CATT, New York City

Prior to the advent of steam railroads the principal and almost the sole method of transportation of goods in large quantities was by caravan or ships.

The caravan has disappeared before the march of civilization, but ships still constitute the only means of transportation between the markets of different continents and also between the differents seaports of the same country.

As a result of the growth of commerce and the progress of ship-building, the largest vessels of today are about 700 feet long, 80 feet wide, 50 feet deep and require a depth of water of 33 feet. Predictions are already made that within the next fifty years vessels will be built 1000 feet long, 100 feet wide and requiring a depth of water of 40 feet.

The new channel entrance to New York Harbor is now being made by the United States Government to provide a depth of water of 40 feet.

In only a few instances do existing conditions in harbors and rivers provide sufficient depth of water to meet the present needs of commerce. To satisfy those requirements channels and harbors are made by artificial means. This is accomplished by removing the material at the bottom so that greater depths and areas may be secured.

The excavation of material is specifically designated as dredging.

Dredging is done by one of two methods, or a combination of these two methods and by one of five types of machines, or a combination of them. One method is by the excavation of the material and depositing it in hopper barges or mud scows and thus transporting it to some suitable place of deposit.

The other method, which I have called "The Hydraulic Method," is by excavating the material and conveying it by means of a moving column of water in a pipe to an adjacent place of deposit.

One of the oldest types is the endless chain dredge. The chain of buckets by revolving excavates the material and then carries it to the highest point of the chain where the buckets in turning over a drum dump their load into a hopper from which by a chute it passes into a pocket either on the same vessel or another vessel alongside, called a mud scow. These pockets have false bottoms or doors, which, when the vessel has reached the dumping ground are opened and the load of material falls out.

This type of machine is of European origin and is largely used there at the present time, but is very seldom used in the United States. This is an efficient tool and can be used to excavate very hard material. It is considered expensive in the matter of repairs and in lost time occasioned thereby.

Another type of machine used at a quite early date is the grapple or clam-shell type, but not used extensively except as a grapple for rock excavation until recently when it has been developed in the United States, and is the most prevalent here, though used but very little in Europe. It is not adapted to excavate material that is designated as very hard. It is about the simplest type, economical and easy to operate, not likely to get out of order or expensive to repair. The part most liable to break, the bucket,—can be carried in duplicate and a broken one removed, and a new one put on in less than half an hour.

A third type is known as the dipper or scoop dredge, which is essentially a steam-shovel mounted on a floating vessel and is usually about double the capacity of a steam-shovel. This type, which is shown in Fig. 1, is confined almost entirely to and was developed in this country. It is considered to be less economical in operation than a dredge of the clam-shell type, but on the other hand it is capable of digging very hard material.

The dipper and clam-shell dredges are mostly used to deposit material into scows alongside. Both types are sometimes used where the material is deposited on the banks of the waterway that is being made.

Another type is known as a hydraulic hopper dredge, and consists of a vessel provided with one or two suction pipes which are lowered so as to come in contact with the material; the upper end of the pipes are connected with suitable pumps which pump the sand into hoppers on board the vessel. When the hoppers are full the vessel proceeds under her own steam to the dumping ground. This type is extensively and almost entirely used for deepening bars at the entrance of harbors and where there is more or less swell. The dredge is kept moving or underway while the dredging is being done. It is only capable of doing work in material almost entirely sand.

Dredging by what I have designated as the second method, consists essentially in disintegrating the material to be excavated immediately adjacent to the opening of a suction pipe in such a manner that the water flowing into the pipe will necessarily carry with it a greater or less amount of material. The water in the pipe under a velocity of from 10 to 20 feet per second conveys the material through the pipe to a place of deposit.

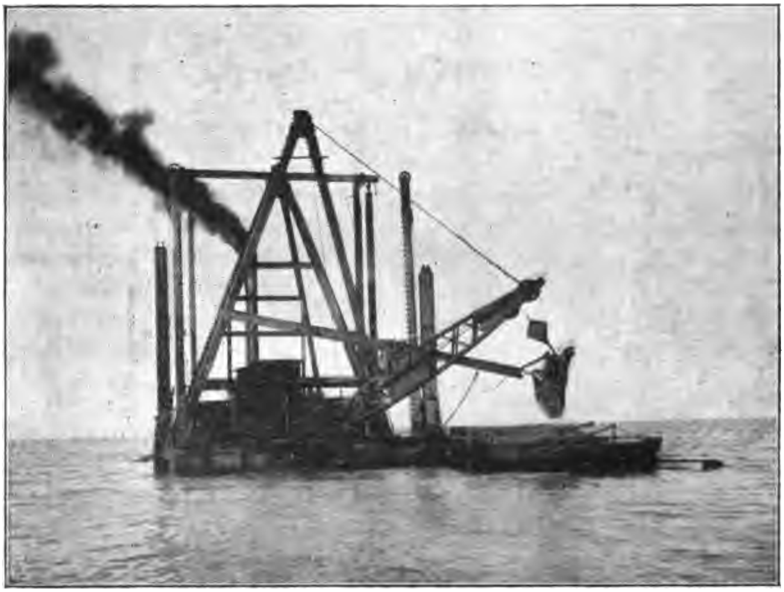

Fig. 1—View of Dipper Dredge at work.

So far as I have been able to learn the first general conception of such a method of operation was worked out in a crude way, but with all the essential elements, by a German named Louis Schwartzkoppf in Germany in 1856. He did some work with a machine of this type and took out a patent for his invention. Nothing further came of this, however.

A machine of quite simple construction was used by an Englishman named Burt on the canals of Holland about 1870-

72. The first work done in this country with this type of dredge was in California in 1876 by a German named Alexander Von Schmidt who constructed a machine and secured a patent for the invention. Von Schmidt undoubtedly did not know of the work of either Schwartzkoppf or Burt and is the pioneer in this country.

After Von Schmidt had built his machine one A. B. Bowers, then living in California, applied for patents and by representation made to the Patent Office, under oath, as to the date of his invention, patents were given him.

In my judgment Bowers was not the inventor, and only deserves to be known in connection with the notoriety gained on account of the patent litigation. The Von Schmidt machines, as first constructed, while workable, were very far from satisfactory and had a very limited field of operation since they were successful only in very soft material or sand.

The writer and his associates in 1887, after many improvements had been made in the Von Schmidt machines by others, undertook to develope this type of machine so that its field of usefulness would be much broader. In other words, to make a commercially successful machine, to the end that the actual cost of doing any given piece of work might be reduced, and to make it possible to estimate the cost closely in advance.

To do this required that an especially designed pump should be provided, and that the entire excavating aparatus be re-constructed on much more efficient lines than anything before attempted, together with many minor matters connected with operating machinery, most of which were the outgrowth of experience gained in actual operation. This development has continued until a thoroughly efficient machine may be said to have been secured.

The type of dredge developed by us is shown in Fig. 2.

A modern hydraulic dredge consists essentially of a hull on which the operating machinery is placed.

The excavation is made by means of a steam engine located on the dredge, actuating by a train of gears a shaft located on a ladder or boom, to the end of which the cutting knives are attached and by which they are made to revolve. The character and construction of the cutting knives are changed as may be

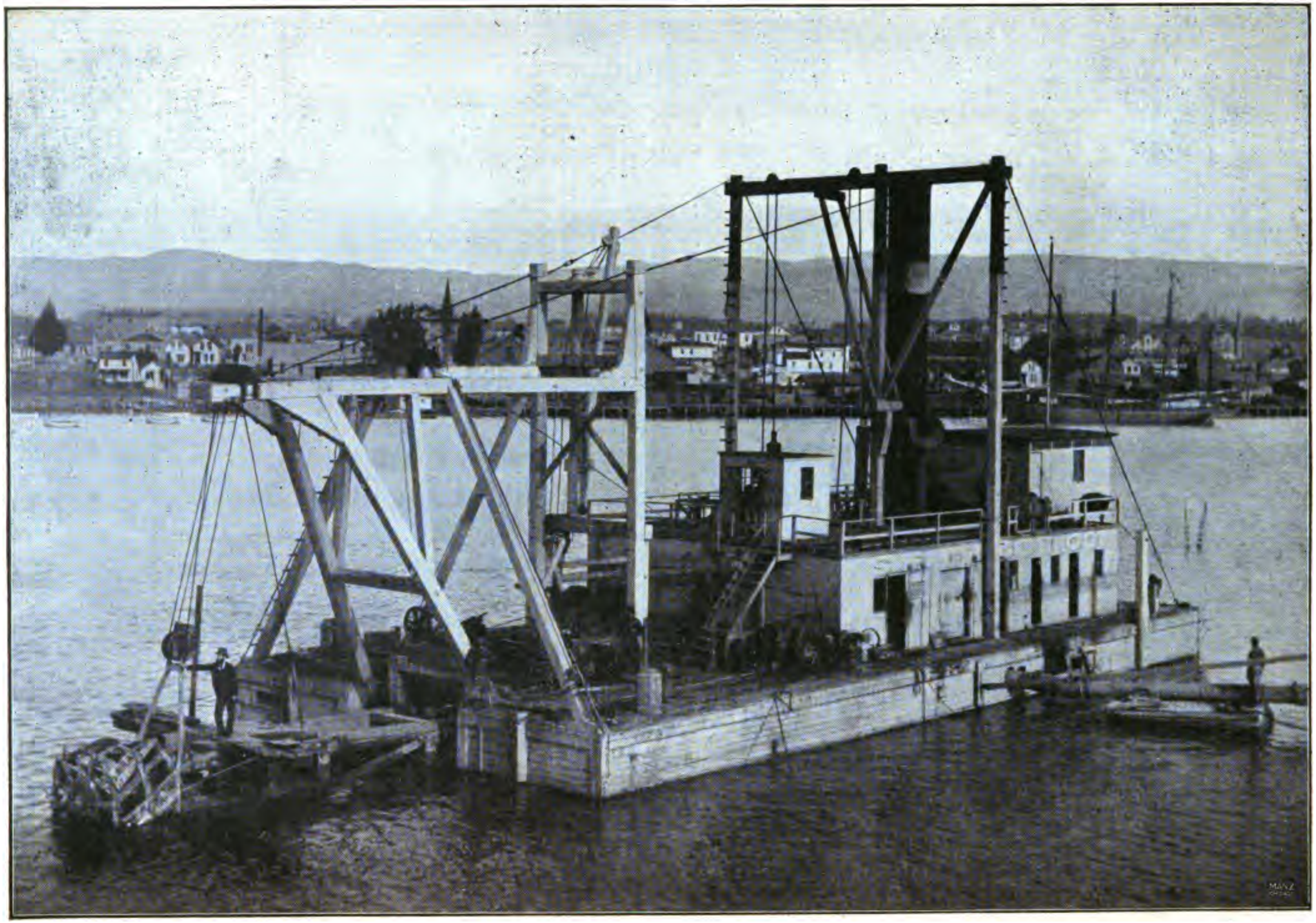

Fig 2—Suction Dredge.

required by the character of the material encountered. One type appears in Fig. 2, and another type is shown more plainly in Fig. 3 herewith.

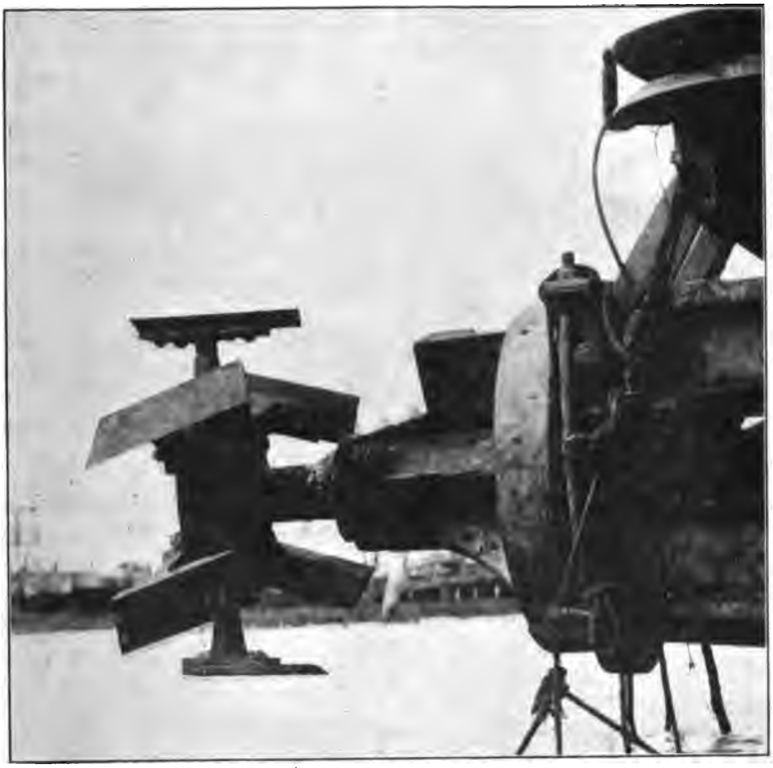

FIG. 3—One type of Cutting Knives for Hydraulic Dredge.

The suction pipe is connected to the ladder and its mouth is brought just as close as possible to the knives at the point where they in revolving cut loose the material. The water flowing into the pipe carries the loosened material with it.

The moving current of water in the pipes is the conveying device by which the material is transported to the place of deposit. The material settles to the bottom in the deposit basin and the surplus water is allowed to run off.

The current of water is produced in the pipes by a specially designed centrifugal pump through which all the water with the material must pass. The pumps are so constructed that the material in passing through shall do the least possible damage by abrasion, and the parts of the pump most liable to wear are made with renewable parts.

The velocity of the current in the pipes varies from about 10 to 20 feet per second, its speed depending on the character of the material, the length of the pipe line, height of discharge, etc.

On the suction side of the pump about one-half of a vacuum is produced, or equivalent to say seven pounds pressure per square inch. The pump is set in the dredge so that it is about at water level. The power of a moving current of water to transport material is much greater than is apparent without investigation. To illustrate: A Vacuum of seven pounds would be capable of lifting a piece of iron the full size of the pipe and 28 inches long. Stones nearly as large as the pipe have been frequently lifted. The heaviest piece in proportion to its size that we have any record of lifting was a solid iron cannon ball 10 1-2 inches in diameter and weighing 160 lbs.

On the discharge side of the pump the velocity is produced by the pressure due to the action of the centrifugal pump, and varies with the different conditions under which the work is done from only a few pounds per square inch to 40 to 60 pounds per square inch. The pump has therefore to be designed to pump against comparatively high heads for centrifugal pumps.

The pipe line through which the material is conveyed to the place of deposit is made of riveted steel plates. For the portion over water it is in sections and carried on floats or pontoons, the sections are connected together with some sort of flexible joint, usually made of a piece of specially constructed hose, or sometimes metal ball and socket joints; in any case they must be of such a character that they will allow a considerable oscillating movement in the pipe.

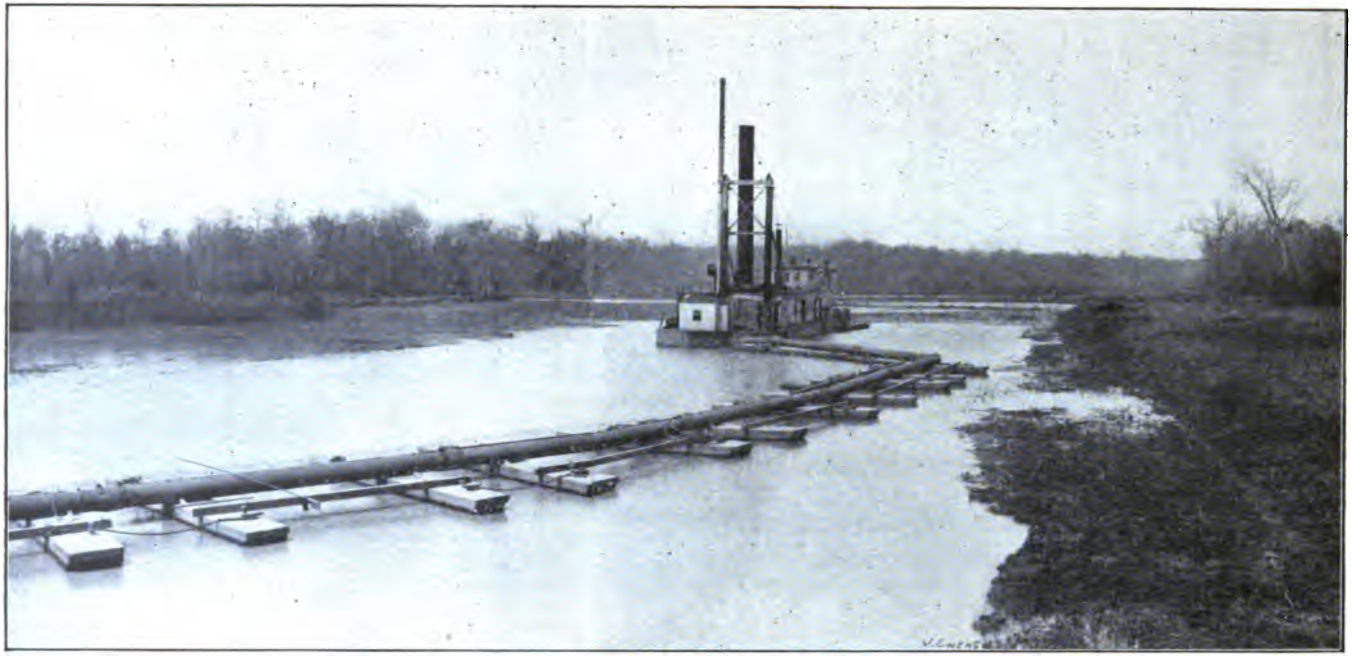

Fig. 4. Hydraulic Dredge at work at Vicksburg, Miss., with the pipe line reaching to the shore. For the portion on land the pipe is made up in sections of convenient lengths for handling, usually 16 or 20 feet long, and these sections are connected together by making them so that one end will telescope into the next piece a few inches with accurate enough fit so they will become tight.

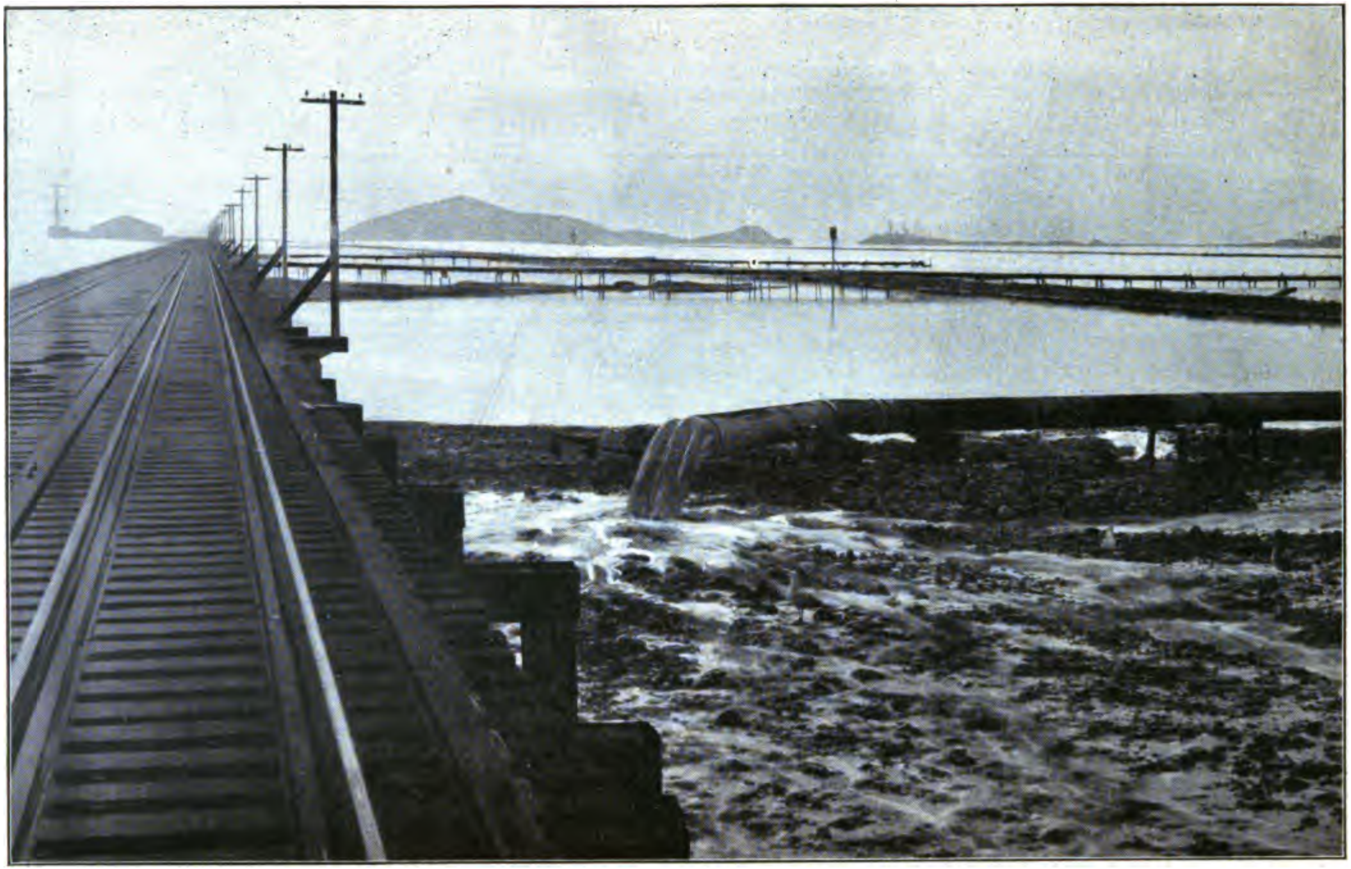

FIG. 5—Shore end of Pipe Line from Hydraulic Dredge at Oakland, California. The figure illustrates the filling in and reclaiming of land with the dredged material.

Fig. 5 shows the shore end of the pipe line at Oakland, Cal.

The usual method of keeping the dredge in place is by means of a vertical anchor or spud located in one end of the machine and about which it swings when in operation.

The dredging is performed substantially as follows:

With the dredge anchored in place, the pump and excavating machinery are put in motion, the ladder is lowered until the excavator comes in contact with the material to be excavated, which it cuts up or disintegrates so that it is carried into the pipe by the current of water, and thus through the pipe to the place of deposit. The excavator is fed into the material by swinging the dredge sideways about the spud as a pivot. This is done by means of lines from the dredge to some sort of anchor on either side. When a swing has been made to one side and the excavation made, the excavator is lowered a proper amount, depending upon the character of the material, usually from a few inches to a foot or two and a swing is made back to the other side, the width of the cut or swath being usually 100 to 200 feet. When this operation has been repeated until the excavator has reached the desired depth the dredge is moved ahead sufficiently to reach material not yet excavated, and this is usually done in quite a simple manner as follows:

The dredge is provided with two spuds, on one of which the dredge swings in the ordinary work of dredging; the second only comes into use in moving the dredge ahead. The dredge is usually moved ahead each time about the length of the excavating apparatus, or 4 to 6 feet. To do this the dredge is swung to the side opposite to that on which the second spud is located. The second spud is then dropped and becomes the anchor spud; the first or working spud is then hoisted; the dredge is swung towards the opposite side until the working spud has moved forward the proper distance, moving in the arc of a circle, of which the second spud is the center and the distance between the two spuds is the radius; the working spud is then dropped and the second spud is hoisted, and the process of excavation proceeds as before. Thus the only machinery required to move the dredge into new material other than the regular machinery required in excavating is one spud and the necessary means of hoisting it and lowering it at the proper time.

In operating the dredge each of the engines, except the main pump engine, and every part of the machinery is under the control of one man called the operator. This is done by means of levers all located in the pivot house.

The size of the machine is generally designated by the size of the pipe or pump. Thus a dredge with 20 inch diameter pipe would be called a 20 inch machine.

The machines vary from small ones of 8 inch to some special ones for special use on the Mississippi River of 34 inch.

The most suitable one for general use is about 20 inch to 26 inch. A 20 inch machine complete with wooden hull will cost about $90,000 to $100,000, and would include the following machinery:

Main pump and engines—Triple expansion, Condensing.

Excavator and engines—Compound Condensing.

Double simple swinging and hoisting engines and machinery.

Electric light and shop engine.

Boiler of water tube type, with special designed semi-marine setting.

Such a machine will excavate in average material suitable to handle by hydraulic method, and with not to exceed an 8 foot lift and 1500 feet of pipe, an average of 150 to 200 cubic yards per engine hour, and should make about 80 to 85 per cent. running time.

Under particularly favorable conditions this may be considerably exceeded.

In one instance a 20 inch machine excavated 297,000 cubic yards in one month, or 700 cubic yards per engine hour. I believe this to be the record output for a machine of this size.

The cost of doing work varies from seven to fifty cents per cubic yard, the average being about fifteen cents per cubic yard. The elements that affect the cost are quite numerous.

1st: The character of the material in reference to the difficulty in digging it.

2nd: The character of the material in reference to the difficulty of transporting it.

a. This is affected by the specific gravity of the material.

b. And also by the coarseness or fineness of the material.

3rd: By the height the material has to be lifted above the water surface.

4th: By the distance the material has to be conveyed.

5th: By the special conditions that surround any given place of work such as will delay the work or make any part of it more difficult to execute.

6th: The cost of fuel.

7th: The cost of labor.

8th: The cost of repairs and the facilities for getting them made.

Many of these can only be approximated. The estimate of cost usually has to be made from such information as a series of borings in the material will disclose of its character.

Experience gained in executing work under almost every possible condition and almost every kind of material is the only possible way to become at all accurate in estimating the cost of work. Yet success in the sense of making a business pay depends almost entirely on ability to accurately estimate the cost.

The conditions necessary to enable the work to be done by this method are:

First: That the material is suitable to be handled by such a method.

Second: That the distance to a suitable place of deposit is not too great.

Third: That the place of deposit is large enough to afford a proper settling basin to enable the material to settle and the surplus water to run off. This last becomes quite important when on the average only about 10 per cent. of the discharge is solid material.

The use of the dredged material for filling of low lands or marshes often becomes a very important sort of by-product on account of the increased value of the filled land.

Sometimes the whole work is done for the purpose of filling lands.

I have in connection with my associates and the companies I have been with, built eleven dredges of the hydraulic type, and they have dredged about fifty million cubic yards of material, and in doing this we have covered a very wide field of operation.

Along the Atlantic and Gulf Coast from Boston, Mass., to Galveston, Texas. On the Pacific Coast from Puget Sound to Southern California. In Central America, Hawaiian Islands and the Philippines.

As illustrative of the work that may be done by this method, I cite the following:

Port Arthur, Texas—Ship canal: A canal about seven miles long through the low lands adjacent to Sabine Lake. The canal is 25 feet deep, 100 feet wide on the bottom, with side slopes of two on one. Over six million cubic yards of material were removed.

The diversion of the mouth of the Yazoo River, Vicksburg, Miss. This consisted in making a new channel for the Yazoo River so that it would flow past the City of Vicksburg. Plans of this work appear in Fig. 6.

This required a new channel for a distance of about six miles. This channel varies in width from 75 feet to 400 feet, and the depth of excavation varied from 0 to 57 feet. A part of the material was used to make levees. About five and a half million cubic yards of material were excavated. In order to adapt the work to execution by hydraulic method, a quite unusual expedient was resorted to.

For a large part of the excavation no available place of deposit existed at a less elevation than about 40 feet above low water. The waters of the Mississippi are below the 10 foot stage for about one-third of the year. In order to overcome this difficulty the outlet of Lake Centenial was closed and the water in the lake held at an elevation of from 26 to 28 feet above low water for two years. In this way the maximum height of discharge above water was never more than 26 feet.

At Seattle, Wash., there is a large area of tide lands, that is, lands which are either bare or which are covered with water, depending on whether the tide is in or out. And as the tide at Seattle averages about 14 feet, this makes the amount of fill in some cases quite important. Waterways were dredged through these low lands and filled on to adjacent tracts, in this way raising them above high tide and making them available for commercial use. About five million cubic yards have been deposited and about one hundred acres of land improved, on which manufactories, warehouses and railroads are now being built.

At Washington, D. C., a large park has been made by depositing on the marsh land along the river the material dredged in making the Potomac River navigable to a depth of 20 feet. About four million cubic yards have been deposited in this way.

At Albany, N. Y., the yard room of the N. Y. C. & H. R. Rd., was enlarged by raising the marsh lands of the Hudson

River with material dredged from the river, and at a less cost than was possible by using a steam-shovel and cars to supply the material.

At Oakland about two miles of railroad trestle was filled in with material dredged from the waterway of Oakland Harbor. See. Fig. 5.

The Government is expecting to keep a depth of water in the Mississippi of not less than 8 feet throughout the entire year by dredging on the bars during the low water stage of the river. This is done by dredging the material so as to make a channel through the bars conveying it away from 500 to 1000 feet from the place where it is dug, and depositing it in the river again.

The Delta: A 34 inch dredge built by us for the Mississippi River Commission made a trial run of thirty days of twenty-four hours each, with a loss of only seventeen hours running time, and developed an average capacity of 1,850 cubic yards per hour and a maximum capacity of 3,213 cubic yards per hour.

A 24 inch machine working at Manila excavated 396,000 cubic yards in one month. The work there is shown in Fig. 7, and consists in building a stone breakwater as a protection to the harbor and excavating inside the breakwater, the excavated material being deposited on the low land in front of the old part of the city. In this way about 160 acres of additional land is made.